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Catalyst-Controlled Dual Reactivity of Sulfonimidamides: Synthesis of Propargylamines and *N*-propargyl sulfonimidamides

Irfana Jesin C. P.[a][b] and Ganesh Chandra Nandi*[a][b]

Abstract: Sulfonimidamides (SIAs) are acting both as surrogate amines and nucleophiles depending on the reaction conditions to access propargylamines and *N*-propargyl SIAs respectively. The amine part of SIAs has been cleaved in an $InCl_3$-catalyzed three-component A^3 coupling reaction with aldehyde and acetylene to yield propargylamine. Moreover, *N*-propargyl SIAs were obtained *via* the direct-imination of propargyl alcohols in the presence of $BF_3.OEt_2$.

Propargylamines are significant building blocks due to their exceptional chemical structure which consists of a nucleophilic amine and an acetylene moiety on the same backbone. Consequently, propargylamines are very much useful for variety of organic transformations to construct diverse kinds of pharmaceutically important compounds and natural products. Moreover, many drugs molecule, such as pargyline (neurodegenerative diseases), rasagyline (Parkinson's disease) and selegiline (Alzheimer's diseases)[1] contain the propargylamine as a core moiety (Figure **1**).

Pargyline
(neurodegenerative diseases)

Rasagyline
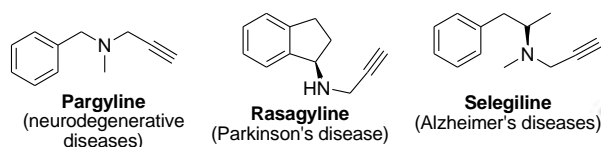(Parkinson's disease)

Selegiline
(Alzheimer's diseases)

Figure 1. Drugs containing propargylamines.

Despite being reported in 1960s by Levchenko et al., the chemistry of sulfonimidamides, *i.e.*, the aza-analogues of sulfonamides with a hexavalent chiral sulfur centre, has not been explored to a great extent. However, the last decade found an increase in interest in the reactivity and applications of SIAs. SIAs have been used as chiral ligand in asymmetric synthesis and as a nitrogen source for aminations, iminations and nitrene transfer reactions. Recently, we reviewed the synthetic and preparative usefulness of SIAs in detail.[2] Their applications in agrochemical and medicinal purpose have also been extensively investigated by Arvidsson et al. in an another review.[3] In addition, lithium salts of highly fluorinated SIAs have been exploited in fuel cells, as super acids, for storage of energy in supercapacitors and in generators.[4]

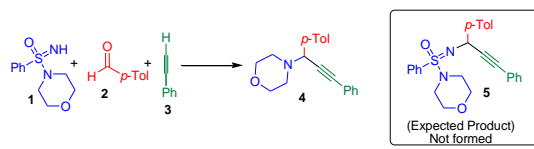As a part of our ongoing research work on the exploration of the chemistry of sulfonimidamides (SIAs), recently we disclosed the mild synthesis of *N*-imidoyl and *N*-oxoimidoyl sulfonimidamides through the three-component coupling of SIAs, azides, and alkynes.[5] A dual C-H/N-H activation protocol to achieve *N*-acyl SIAs also has been developed.[6] In a latest study, we described the design and synthesis of novel sulfonimidoyl azides, *i.e.*, the mono aza-analogues of sulfonyl azides, and applied these azides to provide *N*-acyl SIAs and *N*-sulfonimidoyl amidines in one-step process.[7a] In view of the growing biological and synthetic importance of SIAs, and also of our interest in exploring their chemistry and 'S'-related compounds,[7b-d] herein, we revealed that SIAs can act as amine surrogate under certain conditions to provide propargylamines. Additionally, in the presence of Lewis acid $BF_3.OEt_2$, SIAs reacted with propargyl alcohols to afford *N*-propargyl SIAs. To the best of our knowledge, we disclosed this new property (surrogate amine) of SIAs for the first time.

The transition metal-catalyzed three-component A^3 coupling reactions are one of the most convenient and high-yielding routes to derive propargylamines.[8] A brief literature survey at this stage revealed that in most of the previous A^3 coupling reports, sp^3 hybridised primary or secondary amines were used as nucleophiles in the presence of several metal-catalysts. Till date, only Bolm et al. applied sp^2 hybridized imine to access *N*-propargylsulfoximines *via* A^3 coupling reactions.[9] Consequently, we envisioned that use of SIAs as nucleophile in the A^3 coupling reactions to obtain *N*-propargyl SIAs would be very interesting and synthetically challenging as the imino (S=NH) part of the SIAs is less nucleophilic and less familiar.

We initiated our investigation *via* the treatment of SIA **1** with aldehyde **2** and acetylene **3** in the presence of CuBr in dichloroethane at 80 °C. In a surprising inspection, we found that expected product **5** did not form, but the morpholine group of SIA parted away from **1** and reacted with aldehyde **2** and acetylene **3** to deliver the propargyl amine **4** in 68 % yield (Table 1, entry 1). In addition to **4**, Glaser-Hay product was also formed albeit in less amount. To confirm whether heating is the cause of S-N bond cleavage or not, the reaction was then performed under room temperature (30 °C), again propargyl amine **4** was obtained in less quantity along with lots of unreacted **2** and **3** remaining (Table 1, entry 2). Replacement of solvent DCE with toluene also provided only propargyl amine **4** (42 %). Use of Cu(II) catalysts such $CuBr_2$ and $Cu(OTf)_2$ too ineffective to yield the expected product **5**, but delivered only propargyl amine **4**. Interestingly, application of $InCl_3$ as well yielded compound **4** in very good yield (85 %; Table 1, entry 6), while $ZnBr_2$ was inefficient to drive the reaction forward (Table 1, entry 7).

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Table 1. Reactions of SIAs, aldehydes, and acetylenes under various conditions.[a]

| Entry	Conditions	Yields
1.	CuBr, DCE, 80 °C, 5 h	68 %
2.	CuBr, DCE, rt, 48 h	8 %
3.	CuBr, Toluene, 110 °C, 12 h	42 %
4.	CuBr₂, DCE, 80 °C, 12 h	Trace
5.	Cu(OTf)₂, Toluene, 110 °C, 24 h	CR
6.	InCl₃, Toluene, 110 °C, 4 h	85 %
7.	ZnBr₂, Toluene, 110 °C, 12 h	NR

[a] All the reactants were taken in 1:1:1 ratio and the yields are isolated yields.

The above experiments show that the SIA **1** is acting as a surrogate amine and afforded propargyl amine **4** in the metal-catalyzed A^3 coupling reaction of SIA **1**, aldehyde **2** and acetylene **3**. Since propargyl amines are one of the important scaffolds for pharmaceutically active molecules / natural products, hence we tune our attention to verify the generality of reaction using SIAs **1** as surrogate amine in this A^3 coupling reaction to access propargylamine applying catalyst InCl₃, which gave the best yield (85 %; Table 1, entry 6). Most excitingly, the method discovered a new chemical aspect of SIAs.

The figure **2** demonstrates the generality of the propargyl amines **4** syntheses, where SIAs have been used as amine surrogate. SIAs with various amine group such as morpholine, piperidine and pyrrolidine works equally well to deliver the corresponding product **4**. Moreover, replacement of phenyl group of SIA with *p*-tolyl group too does not affect the product formation. Diverse kind of mono- and di-substituted aromatic aldehydes, with electron withdrawing-/donating- substituents at different position were uniformly tolerated for propargyl amines **4** synthesis. In addition to aromatic aldehydes, heteroaromatic and aliphatic aldehydes as well gave the corresponding propargyl amines in very good to excellent yields. An effort to utilize different types of aromatic and heteroaromatic acetylenes were too effective to derive respective propargyl amines.
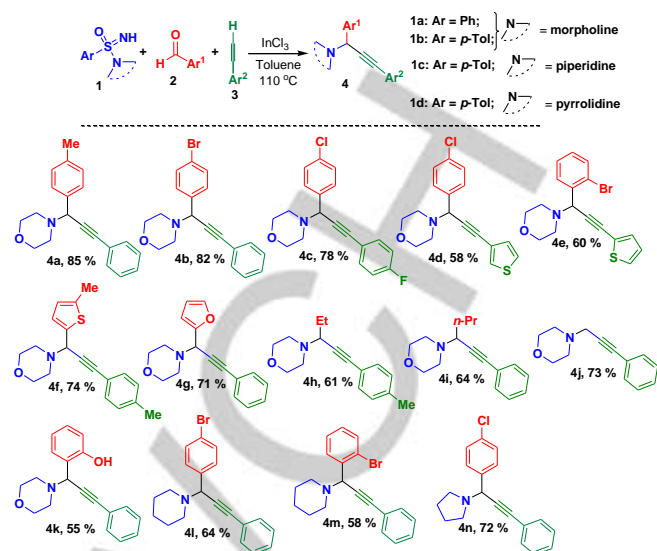
Figure 2. Substrate scope for the synthesis of propargyl amine **4** utilizing SIAs as amine surrogate. Compound **4a,b** and **4j,k** were obtained from **1a**. Compound **4c-i** were prepared from **1b**; while **4l,m** were prepared from **1c**. **1d** was utilized to access **4n**.

In order to investigate the unusual reactivity of SIAs, we analyzed the mass-spectra (GC-MS and HR-MS) of the crude reaction mixture of a respective reaction, and interestingly, we found sulfonamide (**4′**) formed as a side product (Scheme **1**). This observation was encouraging enough to portray the mechanistic steps as demonstrated in scheme **1**. In the presence of InCl₃ (Lewis acid; LA), Sp^3 'N' of SIA **1** reacted with the aldehyde **2** and generated the intermediate **I_a**, which further underwent intramolecular rearrangement (transacylation) to yield **I_b**. A subsequent C-O bond cleavage provides intermediates **I_c** (imminium ion) and the side product sulfonamide **4′** (through abstraction of proton from **3**). In another simultaneous process, in the presence of Lewis acid, terminal aryl alkyne **3** transformed to intermediate **A**, which finally on reaction with the imminium intermediate **I_c** provided propargylamine **4**.
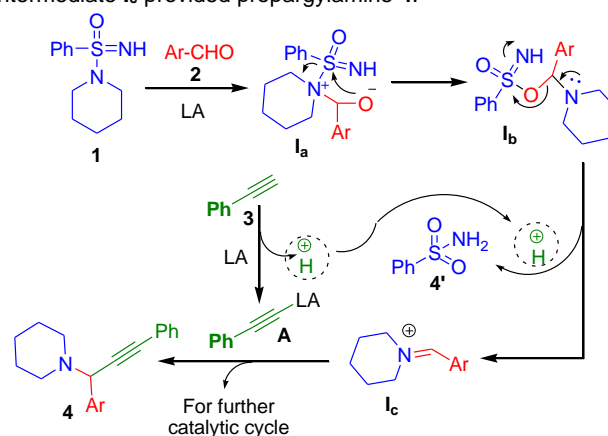

Scheme 1. Probable mechanistic route to *N*-propargyl SIAs

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In all the above experiments *N*-deprotected SIAs have been used. Hence, in order to verify whether *N*-protected SIAs could undergo the similar type of transformation or not, we performed a control reaction of *N*-Boc SIAs **6**, aldehyde and acetylene in the presence of CuBr/DCM at 80 °C for 12 hrs and surprisingly the reaction failed to proceed (Scheme **2**). This observation demonstrates that the imine part (S=NH) of SIAs must be free to access compound **4**.
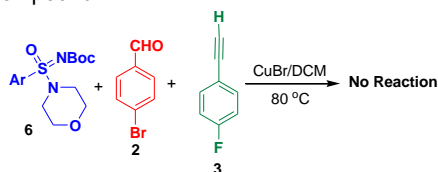

Scheme 2. Use of *N*-protected SIAs for A³ coupling.

As our goal was to obtain propargyl sulfonimidamides, hence we tried a three component coupling of SIA, benzyldibromide and aryl acetylene in the presence of CuCl/Et₃N in MeCN (Scheme **3a**) following a report by Zhang et al.[10] We also utilized silyl protected acetylene according to a literature method by Sakai and co-workers (Scheme **3b**).[11] Unfortunately, none of these methods were fruitful to afford expected propargyl sulfonimidamides **5**.
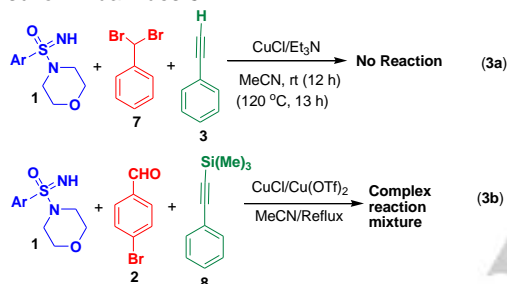
Scheme 3. Alternative protocol for the synthesis of propargyl SIAs.

At this scenario, to construct propargyl SIAs, we went through a different pathway as shown in scheme **4**. We first synthesized propargyl alcohols **9** *via* the treatment of aldehydes **2** and acetylenes **3** following the reported procedures.[12] The synthesized propargyl alcohols **9** were further treated with SIAs **1** in the presence of strong Lewis acid to obtain propargyl sulfonimidamides **10** *via* the nucleophilic substitution of –OH group of **9** with imine part of SIAs **1**.
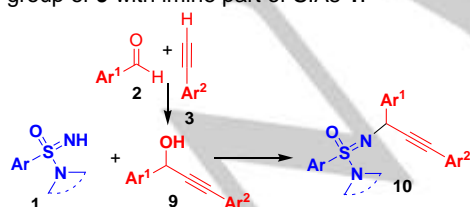
Scheme 4. Synthesis of *N*-propargyl SIAs **10**.

The optimization process was started by treating sulfonimidamide **1** with propargyl alcohol **9** in the presence of Lewis acid InCl₃ as catalyst and acetonitrile as solvent at room temperature. But the reaction did not yield any desire product **10** (Table 2, entry 1). Performing the reaction at high temperature (70 °C) was also unsuccessful and yielded only traces of product (Table 2, entry 2). The use of Bronsted acid *p*-TSA.H₂O for propargylation too found to be ineffective to drive the reaction forward (Table 2, entries 3 and 4). Other metal-catalysts such as, Cu(OTf)₂, Sc(OTf)₃ also did not show any good catalytic activity (Table 2, entries 5-7). The above results prompted us to use stronger Lewis acid BF₃.OEt₂ (1.0 equiv.) in DCM and to our delight the expected propargyl sulfonimidamide **10** was obtained in moderate yield (46 %). In order to enhance the product formation, comparatively stronger trifluoromethane sulfonic acid (CF₃SO₃H) in DCM was used, but lesser amount of product **10** was obtained (Table 2, entry 9). Since BF₃.OEt₂ (1.0 equiv.) provides the better outcome, we tried to optimize its loading. Thus 0.5 equiv. and 1.2 equiv. of BF₃.OEt₂ was applied to inspect the product formation, unfortunately, 0.5 equiv. of acid was inefficient to complete the reaction, while 1.2 equiv. provided lesser amount of product. Thus, utilization of 1.0 equiv. of BF₃.OEt₂ may be taken as optimized reaction condition to derive propargyl sulfonimidamides.

Table 2. Optimization process for the synthesis of *N*-propargyl sulfonimidamides.[a]

S. No.	Conditions	Yields
1	InCl₃ (20 mol %), MeCN, RT, 24 h,	NR
2	InCl₃ (20 mol %), MeCN, 70 °C, 24 h	Trace
3	*p*-TSA.H₂O (20 mol %), MeCN, RT, 24 h	NR
4.	*p*-TSA.H₂O (20 mol %), MeCN, 70 °C, 24 h	Trace
5.	Cu(OTf)₂ (20 mol %), MeCN, RT, 24 h	Trace
6.	Cu(OTf)₂ (1.0 equiv.), MeCN, RT /70 °C, 24 h	Trace
7.	Sc(OTf)₃ (20 mol %), MeCN, RT /70 °C, 24 h	Trace
8.	BF₃.OEt₂ (1.0 equiv.), DCM, RT, 15 mins	46 %
9.	CF₃SO₃H (1.0 equiv.), DCM, RT, 15 mins	24 %

[a] Compounds **1** and **9** were taken in 1:1 ratio and the yields are isolated yields

With the optimized reaction conditions in hand (Table 2, entry 8), we synthesized various *N*-propargyl sulfonimidamides with versatile structural diversity (Figure **3**). Propargyl alcohols with different substitutions at various positions of aryl ring works well for this transformation and provided moderate yield. Both electron donating (-Me) as well as withdrawing substituents (-

Br/-F/-Cl,-CF₃) on the aromatic ring afforded the expected propargyl SIAs. In addition to the structural diversity of propargyl alcohols, various parts of the sulfonimidamides were also successfully altered, such as morpholine has been replaced by pyrollidine and phenyl group has been replaced with *p*-tolyl group. It is worth in mentioning that we got approximately 1:1 diastereomeric mixture for almost all of the products.
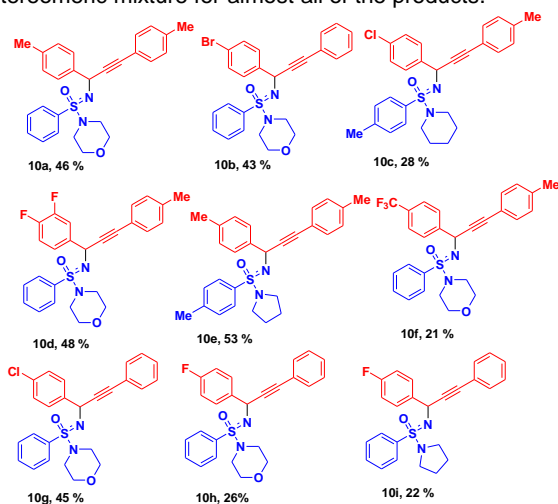
Figure 3. Substrate scopes for the synthesis of *N*-propargyl sulfonimidamides. Yields are based on the combination of diastereomers.

The low to moderate yield of *N*-propargyl sulfonimidamides may be explained through the scheme **5**. In the presence of Lewis acid (or acid: CF₃SO₃H), the propargyl alcohol **9** generated propargyl cation **9I₁**, which could also co-exist in its allenic form **9I₂**. The reaction of propargyl cation **9I₁** with SIAs afforded expected product **10**. Since the "imino" end of SIAs is less nucleophilic, and the intermediates **9I₁** / **9I₂** are not stable enough; hence we are getting lesser yield of propargyl SIAs **10**.
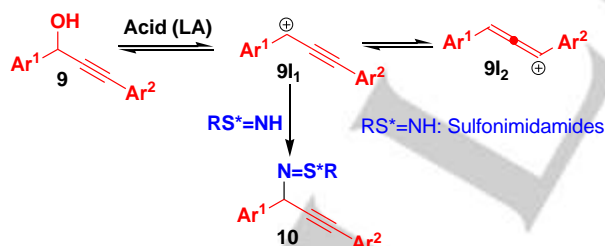
Scheme 5. Probable mechanistic route to *N*-propargyl SIAs.

In conclusion, we explore an unfamiliar characteristic of SIAs, which is acting as surrogate amines in an InCl₃-catalyzed three-component A³ coupling reaction with aldehydes and acetylenes to yield propargylamines in very good to excellent yield. Additionally, we have also developed a protocol where SIAs are functioning as a nucleophile to access *N*-propargyl SIAs *via* the direct-imination of propargyl alcohols in the presence of BF₃.OEt₂. Further research outputs on related area are underway in the laboratory and will publish in due course.

Experimental Section

General

The starting material sulfonimidamides[2] and propargyl alcohols[12] were synthesized in the laboratory following the reported methods. The reagents and catalysts were purchased from various suppliers and used as received. ^{1}H and ^{13}C NMR spectra were recorded on BRUKER NMR spectrophotometer operating at 500 MHz and 126 MHz respectively. CDCl₃ were used as solvent to record NMR spectra. Mass spectra were recorded on Thermo Scientific Exactive mass spectrometer under ESI/HRMS at 60,000 resolutions using ion trap mass analyzer. Melting points were uncorrected.

General procedure for the synthesis of *N*-propargyl amines (4a-n)

To a 1.5 mL toluene solution of sulfonimidamides (1.0 equiv.), aldehydes (1.0 equiv.) and terminal acetylenes (1.0 equiv.), InCl₃ (20 mol %) was added and the reaction mixture was heated at 110 °C for the stipulated period of time. After completion of the reaction, it was directly purified through a filter column chromatography with 2-3 % of ethyl acetate in hexane as eluent.

General procedure for the synthesis of *N*-propargyl sulfonimidamides (10a-i)

To a 1.5 mL dichloromethane solution of sulfonimidamide (1.0 equiv.) and propargyl alcohol (1.0 equiv.) in a 15 mL Schlenk tube, BF₃.OEt₂ (1.0 equiv.) was added at room temperature and was stirred for the required period of time. After completion, the reaction mixture was washed with saturated sodium bicarbonate, water, and extracted with ethyl acetate (3 x 10 mL). The organic layer was then washed with water, dried and purified through column chromatography with 5-7 % of ethyl acetate in hexane as eluent. In almost all cases, we were able to isolate the diastereomers in its pure form.

Characterization data of the isolated compounds

Compound 4a-4n

Compounds **4a**, **4b**, **4g**, **4i-k**, **4l-n** are well known and analytical data (NMR and mass) were compared with the reported literature data,[13] hence the characterization data is not added here. The data of novel compounds **4c-g**, **4h** are mentioned below and attached in the SI file.

Compound 4c

Colourless liquid. ^{1}H NMR (500 MHz, CDCl₃): δ 7.56 (d, *J* = 8.0 Hz, 2H), 7.49-7.47 (m, 2H), 7.33 (d, *J* = 8.5 Hz, 2H), 7.03 (t, *J* = 8.5 Hz, 2H), 4.73 (s, 1H), 3.74-3.71 (m, 4H), 2.60-2.59 (m, 4H). ^{13}C NMR (500 MHz, CDCl₃): δ 162.7 (d, *J* = 248.1 Hz), 136.4, 133.8 (d, *J* = 8.2 Hz), 133.7, 129.9, 128.7, 118.9 (d, *J* = 3.5 Hz), 115.7 (d, *J* = 22.0 Hz), 87.9, 84.2, 67.2, 61.4, 49.9. HRMS (ESI) calcd for C₁₉H₁₇ClFNO [M+H]⁺ 330.1055; found 330.1043.

Compound 4d

Pale yellow liquid. ^{1}H NMR (500 MHz, CDCl₃): δ 7.56-7.46 (m, 3H), 7.33-7.22 (m, 3H), 7.16-7.13 (m, 1H), 4.70 (s, 1H), 3.70 (brs, 4H), 2.57 (brs, 4H). ^{13}C NMR (500 MHz, CDCl₃): δ 136.5, 133.7, 130.1, 129.9, 129.0, 128.5, 125.5, 121.7, 84.1, 83.9, 67.2, 61.5, 49.9. HRMS (ESI) calcd for C₁₇H₁₆ClNOS [M+H]⁺ 318.0714; found 318.0690.

Compound 4e

Pale yellow liquid. ^{1}H NMR (500 MHz, CDCl$_3$): δ 7.74 (dd, J = 8.0, 1.5 Hz, 1H), 7.59 (d, J = 8.0 Hz, 1H), 7.48 (d, J = 3.0 Hz, 1H), 7.32 (t, J = 8.0 Hz, 1H), 7.29-7.26 (m, 1H), 7.19-7.15 (m, 2H), 5.04 (s, 1H), 3.74-3.65 (m, 4H), 2.66-2.64 (m, 4H). ^{13}C NMR (126 MHz, CDCl$_3$): δ 137.2, 133.3, 130.7, 130.1, 129.4, 128.9, 127.0, 125.4, 125.3, 121.8, 84.3, 83.6, 67.2, 61.4, 49.8. HRMS (ESI) calcd for C$_{17}$H$_{16}$BrNOS [M+H]$^+$ 362.0209; found 362.0191.

Compound 4f

Pale yellow liquid. ^{1}H NMR (500 MHz, CDCl$_3$): δ 7.39 (d, J = 8.0 Hz, 2H), 7.13 (d, J = 8.0 Hz, 2H), 7.00 (d, J = 3.0 Hz, 1H), 6.60 – 6.59 (m, 1H), 4.90 (s, 1H), 3.76-3.73 (m, 4H), 2.73 – 2.68 (m, 2H), 2.65 – 2.61 (m, 2H), 2.46 (s, 3H), 2.36 (s, 3H). ^{13}C NMR (126 MHz, CDCl$_3$): δ 140.2, 140.0, 138.4, 131.7, 129.0, 126.2, 124.2, 119.6, 87.5, 83.6, 67.1, 57.9, 49.6, 21.5, 15.4. HRMS (ESI) calcd for C$_{19}$H$_{21}$NOS [M+H]$^+$ 312.1417; found 312.1405.

Compound 4h

Pale yellow liquid. ^{1}H NMR (500 MHz, CDCl$_3$): δ 7.33 (d, J = 8.0 Hz, 2H), 7.10 (d, J = 8.0 Hz, 2H), 3.79 – 3.72 (m, 4H), 3.39 (t, J = 7.5 Hz, 1H), 2.76 – 2.72 (m, 2H), 2.59 – 2.55 (m, 2H), 2.34 (s, 3H), 1.73 (q, J = 7.5 Hz, 2H), 1.07 (t, J = 7.5 Hz, 3H). ^{13}C NMR (126 MHz, CDCl$_3$): δ 138.0, 131.6, 128.9, 120.1, 86.3, 86.2, 67.1, 59.8, 49.7, 26.1, 21.4, 11.2. HRMS (ESI) calcd for C$_{16}$H$_{21}$NO [M+H]$^+$ 244.1696; found 244.1670.

Compound 10a

Diastereomer 1: Yellowish sticky liquid. ^{1}H NMR (500 MHz, CDCl$_3$): δ 7.94 (d, J = 8.5 Hz, 2H), 7.59-7.56 (m, 3H), 7.51 (t, J = 8.0 Hz, 2H), 7.33 (d, J = 8.0 Hz, 2H), 7.15-7.11 (m, 4H), 5.81 (s, 1H), 3.78-3.68 (m, 4H), 3.22 (br, 2H), 3.00 (br, 2H), 2.35 (s, 3H), 2.32 (s, 3H). ^{13}C NMR (126 MHz, CDCl$_3$): δ 138.9, 138.3, 136.8, 134.7, 132.5, 131.6, 129.2, 129.1, 128.8, 128.0, 127.2, 120.3, 90.1, 83.7, 66.6, 47.6, 46.5, 21.5, 21.2. HRMS (ESI) calcd for C$_{27}$H$_{28}$N$_2$O$_2$S [M+Na]$^+$ 467.1764; found 467.1738.

Diastereomer 2: Yellowish sticky liquid. ^{1}H NMR (500 MHz, CDCl$_3$): δ 7.90-7.88 (m, 2H), 7.56-7.54 (m, 3H), 7.50 (d, J = 8.0 Hz, 2H), 7.28 (d, J = 8.0 Hz, 2H), 7.18 (d, J = 8.0 Hz, 2H), 7.03 (d, J = 8.5 Hz, 2H), 5.65 (s, 1H), 3.54-3.50 (m, 4H), 2.86 (br, 2H), 2.74-2.69 (m, 2H), 2.35 (s, 3H), 2.29 (s, 3H). ^{13}C NMR (126 MHz, CDCl$_3$): δ 140.0, 137.9, 137.1, 135.0, 132.6, 131.8, 129.3, 128.8, 128.8, 128.3, 127.3, 120.6, 90.7, 83.4, 66.3, 48.0, 47.0, 21.5, 21.3. HRMS (ESI) calcd for C$_{27}$H$_{28}$N$_2$O$_2$S [M+Na]$^+$ 467.1764; found 467.1743.

Compound 10b

Diastereomer 1: Light yellowish solid, mp 95-98 °C ^{1}H NMR (500 MHz, CDCl$_3$): δ 7.94-7.93 (m, 2H), 7.59-7.57 (m, 3H), 7.53 (t, J = 7.5 Hz, 2H), 7.46-7.43 (m, 4H), 7.33-7.32 (m, 3H), 5.80 (s, 1H), 3.77-3.71 (m, 4H), 3.21 (s, 2H), 3.00 (s, 2H). ^{13}C (126 MHz, CDCl$_3$): δ 141.0, 134.4, 132.7, 131.7, 131.4, 129.1, 129.0, 128.5, 128.5, 128.0, 123.0, 121.3, 90.2, 84.1, 66.5, 47.5, 46.3. HRMS (ESI) calcd for C$_{25}$H$_{23}$BrN$_2$O$_2$S [M+Na]$^+$ 517.0556; found 517.0528.

Diastereomer 2: Light yellowish solid, mp 97-99 °C. ^{1}H NMR (500 MHz, CDCl$_3$): δ 7.90 (d, J = 8.0 Hz, 2H), 7.58-7.50 (m, 7H), 7.40-7.39 (m, 2H), 7.26-7.25 (m, 3H), 5.63 (s, 1H), 3.58-3.54 (m, 4H), 2.92-2.89 (m, 2H), 2.76-2.73 (m, 2H). ^{13}C NMR (126 MHz, CDCl$_3$): δ 141.8, 132.8, 131.9, 131.7, 129.1, 129.0, 128.3, 128.2, 128.1, 123.3, 123.2, 121.4, 90.6, 83.9,

66.2, 47.7, 47.0. HRMS (ESI) calcd for C$_{25}$H$_{23}$BrN$_2$O$_2$S [M+Na]$^+$ 517.0556; found 517.0521.

Compound 10c

Diastereomer 1: Off white solid, mp 100-102 °C. ^{1}H NMR (500 MHz, CDCl$_3$): δ 7.81 (d, J = 8.5 Hz, 2H), 7.65 (d, J = 8.5 Hz, 2H), 7.35 (d, J = 8.0 Hz, 2H), 7.29-7.27 (m, 4H), 7.12 (d, J = 8.0 Hz, 2H), 5.78 (s, 1H), 3.19-3.16 (m, 2H), 2.99-2.96 (m, 2H), 2.41 (s, 3H), 2.35 (s, 3H), 1.71-1.70 (m, 2H), 1.64-1.61 (m, 2H), 1.40-1.37 (m, 2H). ^{13}C NMR (126 MHz, CDCl$_3$): δ 142.9, 141.0, 139.9, 138.3, 132.7, 131.6, 129.4, 129.1, 128.9, 128.3, 128.3, 128.0, 120.4, 90.0, 83.8, 48.3, 46.3, 25.7, 23.8, 21.6, 21.5. HRMS (ESI) calcd for C$_{28}$H$_{29}$ClN$_2$OS [M+Na]$^+$ 499.1581; found 499.1560.

Diastereomer 2: Off white solid, mp 98-100 °C. ^{1}H NMR (500 MHz, CDCl$_3$): δ 7.77 (d, J = 8.5 Hz, 2H), 7.63 (d, J = 8.5 Hz, 2H), 7.34 (d, J = 8.5 Hz, 2H), 7.28-7.27 (m, 4H), 7.04 (d, J = 8.5 Hz, 2H), 5.58 (s, 1H), 2.89 (brs, 2H), 2.77-2.75 (m, 2H), 2.40 (s, 3H), 2.30 (s, 3H), 1.49-1.47 (m, 4H), 1.33-1.31 (m, 2H). ^{13}C NMR (126 MHz, CDCl$_3$): δ 142.9, 141.7, 137.9, 132.9, 132.9, 131.7, 129.4, 128.8, 128.7, 128.6, 128.3, 120.4, 90.4, 83.7, 47.7, 47.6, 25.4, 23.7, 21.6, 21.5. HRMS (ESI) calcd for C$_{28}$H$_{29}$ClN$_2$OS [M+Na]$^+$ 499.1581; found 499.1556.

Compound 10d

Diastereomer 1: Yellowish sticky liquid. ^{1}H NMR (500 MHz, CDCl$_3$): δ 7.94 (d, J = 8.0, 2H), 7.61 (t, J = 7.0 Hz, 1H), 7.55-7.52 (m, 3H), 7.42-7.40 (m, 1H), 7.33 (d, J = 8.0 Hz, 2H), 7.14-7.08 (m, 3H), 5.79 (s, 1H), 3.77-3.71 (m, 4H), 3.21 (brs, 2H), 3.00 (brs, 2H), 2.36 (s, 3H). ^{13}C NMR (126 MHz, CDCl$_3$): δ 150.1 (dd, J = 248.2, 12.6 Hz), 149.5 (dd, J = 246.9, 12.6 Hz), 139.0, 138.6, 134.2, 132.7, 131.4, 129.2, 128.9, 127.8, 123.1 (m), 119.6, 116.7 (d, J = 17.6 Hz), 116.4 (d, J = 17.6 Hz), 89.0, 84.2, 66.4, 47.4, 45.7, 21.4. HRMS (ESI) calcd for C$_{26}$H$_{24}$F$_2$N$_2$O$_2$S [M+Na]$^+$ 489.1419; found 489.1389.

Diastereomer 2: Yellowish sticky liquid. ^{1}H NMR (500 MHz, CDCl$_3$) δ 7.90 (d, J = 7.5 Hz, 2H), 7.59-7.52 (m, 4H), 7.37 (br, 1H), 7.28 (d, J = 8.0 Hz, 2H), 7.16-7.14 (m, 1H), 7.06 (d, J = 8.0 Hz, 2H), 5.60 (s, 1H), 3.61-3.57 (m, 4H), 2.93-2.92 (m, 2H), 2.81-2.79 (m, 2H), 2.31 (s, 3H). ^{13}C NMR (126 MHz, CDCl$_3$): δ 150.4 (dd, J = 245.7, 15.1 Hz), 149.8 (dd, J = 245.7, 15.1 Hz), 139.9, 138.3, 134.8, 132.8, 131.7, 129.0, 128.9, 128.3, 123.1 (m), 120.0, 117.1 (d, J = 17.6 Hz), 116.3 (d, J = 17.6 Hz), 89.4, 84.3, 66.3, 47.5, 46.9, 21.5. HRMS (ESI) calcd for C$_{26}$H$_{24}$F$_2$N$_2$O$_2$S [M+Na]$^+$ 489.1419; found 489.1380.

Compound 10e

Diastereomer 1: Off white solid, mp 85-87 °C. ^{1}H NMR (500 MHz, CDCl$_3$): δ 7.88 (d, J = 8.5 Hz, 2H), 7.58 (d, J = 8.0 Hz, 2H), 7.36 (d, J = 8.0 Hz, 2H), 7.27-7.26 (m, 2H), 7.13-7.10 (m, 4H), 5.80 (s, 1H), 3.42-3.40 (m, 2H), 3.25-3.23 (m, 2H), 2.40 (s, 3H), 2.34 (s, 3H), 2.31 (s, 3H), 1.72-1.68 (m, 4H). ^{13}C NMR (126 MHz, CDCl$_3$): δ 142.8, 137.4, 136.6, 131.6, 129.4, 129.1, 129.0, 128.4, 128.1, 127.3, 127.3, 120.8, 90.1, 81.8, 48.9, 47.0, 25.3, 21.5, 21.2, 21.2. HRMS (ESI) calcd for C$_{28}$H$_{30}$N$_2$OS [M+Na]$^+$ 465.1971; found 465.1941.

Diastereomer 2: Off white solid, mp 90-92 °C. ^{1}H NMR (500 MHz, CDCl$_3$): δ 7.88 (d, J = 8.5 Hz, 2H), 7.58 (d, J = 8.0 Hz, 2H), 7.27-7.26 (m, 4H), 7.17 (d, J = 7.0 Hz, 2H), 7.03 (d, J = 8.0 Hz, 2H), 5.63 (s, 1H), 3.13-3.11 (m, 2H), 3.01-2.99 (m, 2H), 2.40 (s, 3H), 2.35 (s, 3H), 2.29 (s, 3H), 1.63-1.60 (m, 4H). ^{13}C NMR (126 MHz, CDCl$_3$): δ 142.6, 140.0, 137.5, 136.6, 133.9, 131.6, 129.3, 128.9, 128.6, 128.2, 127.0, 120.7, 90.9 83.1, 48.3, 47.8, 25.1, 21.4, 21.4, 21.1. HRMS (ESI) calcd for C$_{28}$H$_{30}$N$_2$OS [M+Na]$^+$ 465.1971; found 465.1947.

Compound 10f

Yellowish sticky liquid. ^{1}H NMR (500 MHz, CDCl$_3$): δ 7.94 (d, J = 7.5 Hz, 2H), 7.82 (d, J = 8.0 Hz, 2H), 7.60-7.53 (m, 5H), 7.33 (d, J = 8.0 Hz, 2H), 7.14 (d, J = 8.0 Hz, 2H), 5.88 (s, 1H), 3.80-3.69 (m, 4H), 3.22 (brs, 2H), 3.01 (brs, 2H), 2.36 (s, 3H).^{13}C NMR (126 MHz, CDCl$_3$): δ 138.7, 137.5, 134.2, 132.8, 131.6, 130.1, 129.3, 129.0, 128.0, 127.7, 127.0, 125.4, 120.5, 89.5, 84.0, 66.5, 47.5, 46.3, 21.6. HRMS (ESI) calcd for C$_{27}$H$_{25}$F$_3$N$_2$O$_2$S [M+Na]$^+$ 521.1481; found 521.1452. (We were able to isolate only one isomer in its pure form).

Compound 10g

Diastereomer 1: Light brown solid, mp 87-90 °C. ^{1}H NMR (500 MHz, CDCl$_3$): δ 7.94 (d, J = 7.5 Hz, 2H), 7.64 (d, J = 8.0 Hz, 2H), 7.59 (t, J = 7.5 Hz, 1H), 7.53 (t, J = 7.5 Hz, 2H), 7.45-7.43 (m, 2H), 7.33-7.29 (m, 5H), 5.83 (s, 1H), 3.79-3.69 (m, 4H), 3.21-3.20 (m, 2H), 3.02-3.00 (m, 2H). ^{13}C NMR (126 MHz, CDCl$_3$): 140.5, 134.4, 133.1, 132.7, 131.7, 129.0, 128.7, 128.5, 128.5, 128.5, 128.0, 123.0, 90.2, 84.1, 66.5, 47.5, 46.2, 25.7. HRMS (ESI) calcd for C$_{25}$H$_{23}$ClN$_2$O$_2$S [M+Na]$^+$ 473.1061; found 473.1035.

Diastereomer 2: Light brown solid, mp 91-93 °C. ^{1}H NMR (500 MHz, CDCl$_3$): δ 7.80 (d, J = 7.0 Hz, 2H), 7.53 (d, J = 8.5 Hz, 2H), 7.49 (t, J = 7.5 Hz, 1H), 7.43 (t, J = 7.5 Hz, 2H), 7.30-7.28 (m, 2H), 7.26 (d, J = 8.5 Hz, 2H), 7.15-7.13 (m, 3H), 5.54 (s, 1H), 3.48-3.44 (m, 4H), 2.82-2.80 (m, 2H), 2.66-2.64 (m, 2H). ^{13}C NMR (126 MHz, CDCl$_3$): δ 141.1, 134.6, 133.1, 132.6, 131.7, 128.8, 128.6, 128.6, 128.1, 128.0, 128.0, 123.1, 90.5, 83.7, 66.1, 47.5, 46.8, 25.7. HRMS (ESI) calcd for C$_{25}$H$_{23}$ClN$_2$O$_2$S [M+Na]$^+$ 473.1061; found 473.1028.

Compound 10h

Colorless sticky liquid. ^{1}H NMR (500 MHz, CDCl$_3$): δ 7.94 (d, J = 7.0 Hz, 2H), 7.68-7.65 (m, 2H), 7.59 (t, J = 7.5 Hz, 1H), 7.53 (t, J = 7.5 Hz, 2H), 7.45-7.43 (m, 2H), 7.33-7.32 (m, 3H), 7.02 (t, J = 8.5 Hz, 2H), 5.84 (s, 1H), 3.80-3.69 (m, 4H), 3.22 (brs, 2H), 3.01 (brs, 2H). ^{13}C NMR (126 MHz, CDCl$_3$): δ 165.6 (d, J = 245.6 Hz), 141.1, 137.8, 136.2, 135.1, 132.5 (d, J = 8.82 Hz), 132.4, 132.0, 131.9, 131.4, 126.5, 118.6 (d, J = 21.4 Hz), 93.9, 87.5, 70.0, 51.0, 49.6. HRMS (ESI) calcd for C$_{25}$H$_{23}$FN$_2$O$_2$S [M+Na]$^+$ 457.1356; found 457.1344 (We were able to isolate only one isomer in its pure form).

Compound 10i

Diastereomer 1: Colorless sticky liquid. ^{1}H NMR (500 MHz, CDCl$_3$): δ 8.01 (d, J = 7.0 Hz, 2H), 7.69-7.66 (m, 2H), 7.56 (t, J = 7.5 Hz, 1H), 7.52-7.46 (m, 4H), 7.32-7.31 (m, 3H), 7.01 (t, J = 8.5 Hz, 2H), 5.83 (s, 1H), 3.45-3.41 (m, 2H), 3.29-3.25 (m, 2H), 1.74-1.70 (m, 4H). ^{13}C NMR (126 MHz, CDCl$_3$): 162.0 (d, J = 244.4 Hz), 137.9, 136.1, 132.2, 131.6, 128.9 (d, J = 8.82 Hz), 128.7, 128.3, 128.1, 127.8, 123.3, 114.9 (d, J = 21.4 Hz), 90.8, 83.5, 48.8, 46.4, 25.2. HRMS (ESI) calcd for C$_{25}$H$_{23}$FN$_2$OS [M+Na]$^+$ 441.1407; found 441.1380.

Diastereomer 2: Colorless sticky liquid. ^{1}H NMR (500 MHz, CDCl$_3$): δ 8.00 (d, J = 7.0 Hz, 2H), 7.69-7.66 (m, 2H), 7.55 (t, J = 7.0 Hz, 1H), 7.50 (t, J = 7.5 Hz, 2H), 7.39-7.37 (m, 2H), 7.24-7.23 (m, 3H), 7.06 (t, J = 8.5 Hz, 2H), 5.65 (s, 1H), 3.16-3.14 (m, 2H), 3.03-3.01 (m, 2H), 1.65-1.63 (m, 4H). ^{13}C NMR (126 MHz, CDCl$_3$): δ 162.1 (d, J = 246.9 Hz), 138.7, 136.7, 132.3, 131.8, 128.9, 128.8, 128.2, 128.1, 127.9, 123.5, 115.2 (d, J = 22.6

Hz), 90.9, 83.4, 48.4, 47.6, 25.3. . HRMS (ESI) calcd for C$_{25}$H$_{23}$FN$_2$OS [M+Na]$^+$ 441.1407; found 441.1378.

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COMMUNICATION

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Layout 2:

COMMUNICATION

We identified a new property of sulfonimidamides, which is acting as a surrogate amine in a A^3 coupling reaction to yield propargylamines. Additionally, propargyl SIAs also have been synthesized *via* direct-imination of propargyl alcohols.
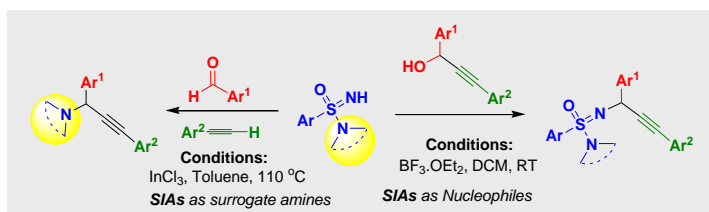
Irfana Jesin C. P., Ganesh Chandra Nandi*

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Catalyst-Controlled Dual Reactivity of Sulfonimidamides: Synthesis of Propargylamines and *N*-propargyl sulfonimidamides